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Ms. Aileen Chia

Director General (Telecoms and Post)

Infocomm Media Development Authority of Singapore

10 Pasir Panjang Road

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Singapore 117438

Re: Consultation on the Proposed Approaches to Introduce the Next Generation of Mobile Services

Dear Ms. Chia,

Ruckus Wireless would like to submit the following response to the consultation on the various aspects of 5G technology development and spectrum requirements in a data centric environment, and the increasing heterogeneity of networks using unlicensed (aka license exempt), licensed, and coordinated-shared spectrum bands.

About Ruckus Wireless

Beginning operations in June 2004, Ruckus Wireless, Inc. is one of the world's fastest growing wireless technology companies. Ruckus offers a broad range of advanced indoor and outdoor "Smart Wi-Fi" systems for service providers and enterprises. The company is credited with developing the first adaptive antenna (Smart Wi-Fi) technology that improves the reliability, performance and capacity of Wi-Fi networks. Ruckus recently announced its line of "OpenG" LTE products, which bring the simplicity and economics of Wi-Fi to the market for in-building cellular services.

According to Dell'Oro's Q3 2015 report, Ruckus is #1 in the Service Provider Wi-Fi market with 38% marketshare and #3 in the Enterprise Wireless LAN market. With approximately 61,000 end customers and more than 10,000 channel partners worldwide, Ruckus sells its Wi-Fi systems directly to broadband providers and indirectly to enterprise customers through a global network of value-added partners.

Ruckus Wireless is a business unit of Brocade Communications Systems, Inc.

Responses to the Consultation

Question 1: IMDA would like to seek views and comments on the estimated timeline for the deployment of 5G. Besides ensuring that spectrum is made available in a timely manner, what other regulatory measures could assist in facilitating the deployment of 5G technology and applications? What other use cases should IMDA take note of when developing the regulatory framework?

Ruckus agrees with IMDA's assessment of 5G as a comprehensive, "umbrella" description of a set of radio access technologies, architectural enhancements, and virtualization/decentralization of function that will achieve the goals of IMT-2020. In terms of radio access technologies, 5G will incorporate traditionally IEEE oriented technologies, such as the 802.11 and 802.15 families, as well as the traditionally 3GPP oriented technologies, such as LTE-Advanced Pro and 5G New Radio (NR). We also agree with IMDA that 5G access will be dependent upon spectrum available for both licensed and unlicensed operation. However, we also believe that coordinated-shared spectrum (CSS) frameworks, such as CBRS and LSA, will play a key role in meeting the spectrum demands for 5G.

A recent chart from Qualcomm[1] underscores the need for a balanced blend of licensed, unlicensed, and coordinated-shared spectrum to support 5G deployments of 3GPP-based technologies:

Source: Qualcomm

Ruckus urges IMDA to pursue a balanced spectrum policy for 5G, ensuring that adequate spectrum is available for both licensed and unlicensed operation, and further encourages IMDA to investigate the use of coordinated-shared spectrum frameworks to open more spectrum for commercial uses for 5G.

The estimated timeline for the deployment of 5G included in the consultation is a helpful tool for the overall planning of spectrum availability. However, industry is moving quickly to make use of the new

[1] Qualcomm: "3GPP starts study on 5G NR spectrum sharing"
https://www.qualcomm.com/news/onq/2017/04/26/3gpp-starts-study-5g-nr-spectrum-sharing

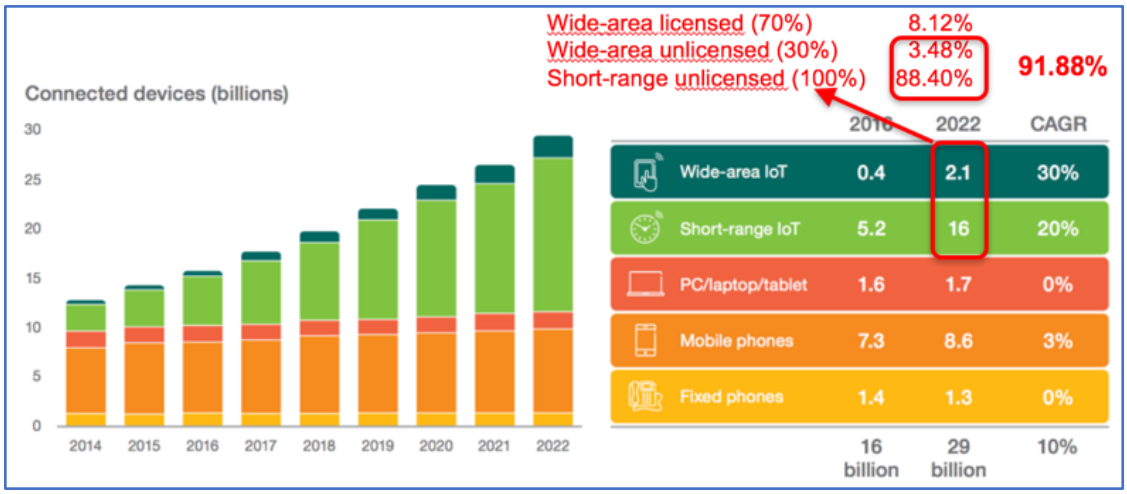
allocations in both the mid-band (3.4-4.2 GHz especially) and high-band (e.g. 64-71 GHz) and IMDA should consider acting more expeditiously to make both mid-band and high-band spectrum available for 5G, especially in ranges that are being made available in large portions of the world in the near future and where industry development is already active.

Question 2: To facilitate and understand potential spectrum requirements for IoT deployments in Singapore, IMDA would like to seek views on the following:

i) Based on the current spectrum allocated for mobile services in the sub-1 GHz frequency bands, are there further suitable spectrum resources that could be released to support both IoT and LTE services?

It is critical to understand that unlicensed spectrum is expected to connect the vast majority of IoT devices, and therefore ensure that adequate unlicensed spectrum in the low-band and mid-band is available to meet that demand.

IMDA notes the Ericsson Mobility Report and its forecasts for IoT connectivity. IMDA also notes some of the unlicensed Low-Power Wide Area Network (LPWAN) technologies, such as SigFox, LoRa, Weightless, etc…, which Ericsson forecasts will connect 30% of the wide-area IoT devices in 2022. Of even greater significance is Ericsson's forecast that 88.4% of IoT devices will be connected using short-range technologies such as Wi-Fi, Bluetooth, and ZigBee in 2022[2], with unlicensed spectrum as the underlying medium. When the short-range and wide-area unlicensed figures are combined, the Ericsson report indicates that 91.8% of IoT devices will be connected via unlicensed spectrum in 2022.



Source: Ericsson

Ruckus encourages IMDA to pursue policies that will 1) enable the most efficient uses of the existing unlicensed designations, and 2) create additional low-band and mid-band unlicensed designations.

[2] Ericsson Mobility Report, November 2016
https://www.ericsson.com/assets/local/mobility-report/documents/2016/ericsson-mobility-report-november-2016.pdf

Question 3: IMDA would like to seek views and comments from industry on what they consider will be the key technologies for 5G and whether current regulatory frameworks sufficiently facilitate the deployment of such technologies.

As noted in our response to Question 1, Ruckus believes that regulators and policymakers will need to adopt a balanced spectrum policy that includes adequate spectrum under licensed, unlicensed, and coordinated-shared spectrum frameworks. The licensed and unlicensed frameworks are well established and understood. On the other hand, coordinated-shared spectrum frameworks are relatively new. As these CSS frameworks can make additional spectrum available via dynamic incumbent protections and also enable new use cases which will be key for 5G, such as private cellular and industrial IoT, we encourage IMDA to strongly consider these types of frameworks as another spectrum management option for its 5G strategy. One helpful resource could be a recent Wireless Broadband Alliance whitepaper paper on coordinated shared spectrum, available at: http://www.wballiance.com/resource/coordinated-shared-spectrum/ .

Question 7: If it is only the extended C-band that is considered for IMT, would the migration of existing satellite users to the other parts of the C-band (i.e. 3.7- 4.2 GHz) impact their service provisioning?

Ruckus supports IMDA's proposal that the extended C-band could be made available for in-building uses for MBB coverage with small cells. Access to in-building use of the extended C-band should be made available on a permissive basis to private entities (such as building owners, Enterprises, and venue operators) in order to make the most efficient use of the spectrum and to encourage deployments. This type of in-building permissive access could be granted on a 'license by rule' basis, such that users would be required to acknowledge and accept their responsibility to operate on a non-interference basis with the existing FSS and TVRO services. In-building deployments by private entities could be utilized to support a number of 5G use cases, including private cellular networks, neutral-host networks, and industrial IoT services. Neutral host networking support for shared spectrum cellular is being developed within industry organizations such as the MulteFire Alliance and CBRS Alliance, and is maturing rapidly.

Ruckus would note that CSS frameworks encompassing dynamic coordination could be utilized to protect the operations of the limited number of existing satellite users in the extended C-band in Singapore, while making the band available for new small cell operations. This would provide a faster path to MBB operation in the extended C-band than requiring a partial or full relocation of the satellite incumbents. If a dynamic CSS framework were implemented, in-building permissive access could be coordinated actively by the supervising spectrum management system(s).

Question 8: Considering the challenges of co-channel deployment of FSS and IMT services in the extended C-band, IMDA would like to seek views and comments on the coexistence measures for adjacent bands and cross border operations.

A CSS framework could be constructed to account for both the adjacent bands (e.g. OOBEs and rolloffs) and territorial borders. Small cell radios could be required to register their operating location and characteristics with the supervising spectrum management system(s), and also to adjust their output power in response to commands from the spectrum management system. This allows infrastructure equipment to be uniformly developed, engineered, and deployed, but ensures that when a MBB small

cell is geographically operating near a territorial border or is operating in a frequency range near the band edge, it's power can be controlled such that it will not exceed the appropriate levels.

Question 9: IMDA would like to seek views and comments on whether there are other frequency bands in the 1-6 GHz frequency band that IMDA should consider for IMT / 5G.

As we noted in our response to Question 1, 5G will be a comprehensive set of access technologies encompassing 3GPP, IEEE, and IoT-specific waveforms and protocols. All of these technologies are expected to make extensive use of unlicensed spectrum, especially in the mid-band where 2.4 GHz and 5 GHz are already heavily utilized. Our responses to Questions 2, 15, 16, 17, 18, and 19 all support the increasing demands on mid-band unlicensed spectrum.

Ruckus recommends that IMDA consider opening a consultation on the feasibility of unlicensed operation in the 5925-7250 MHz range. There is activity in both the United States and Europe around unlicensed operation in this range, with the EC/CEPT recently opening studies on 5925-6425 MHz. The proposals for unlicensed use advocate for a sharing framework that would provide appropriate protections for FSS and Fixed Wireless incumbents. The propagation characteristics, adjacency to the existing 5 GHz unlicensed designations, and incumbent services all support the viability of the 6 GHz band for unlicensed usage.

While the 5925-7250 MHz band technically falls above the 6 GHz upper limit that IMDA specified, our interpretation was that IMDA was seeking input on "mid-band" spectrum needs for 5G. As such, we believe our response is in keeping with the goals of the consultation.

Question 10: IMDA would like to seek your views and comments on the following:
i) The role mmWave bands will play in delivering the vision of 5G, in particular, what services could not be delivered by alternative frequency bands and / or technologies;
ii) The amount of spectrum required in the mmWave spectrum bands to meet 5G applications that will require higher bandwidths; and
iii) The specific mmWave bands that you consider should be a priority in Singapore for IMT services and why?

mmWave bands are well suited to short range transmission of very wideband signals to achieve extremely high data rates. Especially at the high range of mmWave (~60-80 GHz), the propagation is so limited (as IMDA notes) that spectral reuse is achievable at a very local level.

As noted in the consultation, the IEEE and Wi-Fi Alliance have developed specifications and standards for WiGig services at ~60 GHz. Regulators in the United States, United Kingdom, Germany, China, South Korea, and Japan have designated this band for unlicensed operation. The US FCC also recently moved to further designate the 64-71 Ghz band for unlicensed operation. Initially envisioned for in-building, or even in-room, applications, the foundational technology and chipsets are also being utilized for outdoor distribution networks.

Anticipated mmWave unlicensed 5G services include:

- wireless connectivity for virtual reality devices,

- 'wireless HDMI' for UHD (8K) and later generation video,
- immervise augmented reality,
- wireless distributions networks (i.e. 'wireless fiber'), for example Facebook's Terragraph system,
- wireless backhaul for cellular and Wi-Fi access networks.

Ruckus would note that mmWave unlicensed backhaul solutions in the 60-70 GHz range are quite complementary to Wi-Fi access networks operating in the traditional 2.4 and 5 GHz unlicensed bands. Because of the wide bandwidths available, the mmWave backhaul systems are able to provide sufficient capacity to transport the offered load from the latest generation Wi-Fi access (802.11ac, and the forthcoming 802.11ax), do not compete for spectrum resources with the access network, and are deployable by a much larger ecosystem.

Question 15: Considering the current regulations/policies for licence-exempt use and the possibility of LTE-U interfering with Wi-Fi users, IMDA would like to seek views and comments on the following:
i) The adoption of LBT to facilitate sharing of licence-exempt spectrum and whether there would be any implication arising from such a requirement;
ii) The need for further technical requirements and regulatory measures to facilitate the sharing of licence-exempt spectrum in an efficient and fair manner; and
iii) The need for companies with commercial LTE-U networks to upgrade to LAA once the software/hardware products are commercially available.

i. There has been a great deal of industry activity around LBT-based sharing of unlicensed spectrum between Wi-Fi and LTE. IMDA noted the Wi-Fi Alliance Coexistence Task Group's work and resulting testplan. There has also been extensive discussion and research into coexistence in the ETSI Broadband Radio Access Network (BRAN) group, as well as within 3GPP RAN4. While there are still some matters under discussion (please note the series of liaison exchanges between IEEE and 3GPP related to coexistence parameters), a good amount has been learned as parties from the cellular and Wi-Fi communities have engaged with one another in these contexts.

   If IMDA were to require LBT-based sharing of unlicensed spectrum, all of this broad, cross-industry activity and the resulting work products could be applied to Singapore's situation.

ii. No comment.

iii. As noted above in our response to Question 15(i), a requirement for all mobile operators to eventually deploy and operate only LAA networks (as opposed to LTE-U networks) would ensure that Singapore would benefit from the significant industry efforts to understand and optimize coexistence. Further, such a requirement would produce a relatively *"even playing field"* upon which Wi-Fi, LAA, LWA, and MulteFire could all contend for the spectrum resources under a common framework (while again noting some of the ongoing discussions around specific coexistence parameters and threshholds).

Question 16: During the interim period before regulations are finalised, IMDA plans to facilitate industry trials for LAA/LTE-U technologies. As such IMDA would like to seek views and comments on the following:
i) Besides the information listed in Para 80, should MNOs/MVNOs interested in conducting LTE-U trials submit any further information for IMDA's assessment; and
ii) To minimise impact to Wi-Fi users, should IMDA limit LAA/LTE-U trials to parts of the 5 GHz licence-exempt spectrum?

i. The information (site survey results and proposed parameters fro LTE-U deployment) outlined in Para 80 seems comprehensive for the pre-deployment phase. For the impact analysis phase it would be helpful for operators to provide the specifics (e.g. location, operating frequency and power, etc…) of the LTE-U base station radios. If they are able to provide the number of LTE-U clients (UEs) connected to each base station radio over a given time sample, that would also be useful in determining impacts and possible causes.

ii. While we understand and are supportive of IMDA's intention to limit the impact of LTE-U trials on existing Wi-Fi deployments (such as the popular Wireless@SG public service) and agree that trials should initially be conducted in areas where there are limited Wi-Fi users [Para 80(i)], we would recommend that subsequent trials be conducted in proximity to areas of moderate, and even heavy, Wi-Fi usage. These later trials would be helpful in assessing the efficacy of LTE-U in congested environments, as well as the impacts on Wi-Fi usage in those areas. As indicated in Para 80(ii), these later trials of congested environments could be limited to portions of the 5 GHz band in order that Wi-Fi users could continue to access the other portions without the impacts of LTE-U (presuming some type of dynamic channel selection, or RRM, mechanisms that would trigger a channel change based on the environment).

Question 17: IMDA would like to seek views and comments on the following:
i) The possibility of deploying LAA and / or MuLTEfire in other frequency bands besides the licence-exempt 5 GHz band; and
ii) The regulatory and coexistence measures that should be adopted for MuLTEfire.

i. 3GPP has a study item that is considering LAA/eLAA operation in the CBRS band (3550 – 3700 MHz) in the United States. LAA/eLAA channel access mechanisms are not specific to the 5GHz band, and should be theoretically possible in any band where LBT may be utilized. Of course, 3GPP would be responsible for adding other unlicensed bands for LAA/eLAA SDL or CA operation.

ii. MulteFire has not been the focus of broad, cross-industry collaboration regarding Wi-Fi coexistence, as opposed to LTE-U and LAA which have received a great deal of attention. Due to this, and the fact that MulteFire's control signaling also utilizes unlicensed spectrum (unlike LTE-U and LAA that maintain the control signaling in the licensed spectrum "anchor" band), the coexistence between MulteFire and Wi-Fi over varying contention environments is more uncertain at this time. We agree with IMDA's preliminary view that it could apply the same regulations as for LAA to MulteFire, however we would recommend that IMDA assess future studies and trials that analyze MulteFire coexistence specifically, and revisit the MulteFire regulations as necessary.

Question 18: Considering that the LWA approach would not create coexistence issue with Wi-Fi users, would this approach be better suited for countries with extensive Wi-Fi usage?

Ruckus believes that LWA is currently the best solution to directly increase LTE RAN performance utilizing unlicensed spectrum. In addition to the fact that LWA utilizes the native 802.11 PHY/MAC so that Wi-Fi coexistence is transparent, in the 3GPP non-colocated mode, the large installed base of Enterprise and Carrier Wi-Fi access points could be upgraded to support LWA.

In our view, LTE-U and LAA will likely be deployed in a colocated base station, with both the licensed band radio and unlicensed 5 GHz radio integrated into a single small cell. The differences in propagation between the lower frequency licensed bands and 5 GHz unlicensed, coupled with possible variances in regulated power levels, will result in suboptimal coverage and/or spectral reuse in an integrated base station.

Conversely, with non-colocated LWA the Wi-Fi access points can be placed for optimal 5 GHz coverage, capacity, and spectral reuse (standard and well-understood Wi-Fi deployment optimization), while the licensed band eNodeBs are placed at optimal locations for their operating frequencies and characteristics.

It is certainly the case that 802.11 channel access and contention are well understood in areas of extensive Wi-Fi usage. Because LWA utilizes the same 802.11 mechanisms as Wi-Fi, it is accurate to say that these scenarios, associated issues, and remediations would be better understood than with LTE-U, LAA, or MulteFire.

Question 19: IMDA would like to seek views on how the above approaches (i.e. LAA, MuLTEfire and LWA) would enhance the capacity of the mobile network in ways that Wi-Fi offloading is not able to achieve.

The most significant difference between these approaches and traditional Wi-Fi offloading is that the unlicensed spectrum access is integrated directly into the LTE RAN. The experience to the end user should be fully transparent and would not require any manual intervention in order to utilize the unlicensed spectrum for LTE services.

However, Wi-Fi is the dominant and preferred wireless broadband technology (as IMDA noted in the consultation). This will not change in the foreseeable future. The fact that Wi-Fi networks can be deployed and operated by all types of entities guarantees there continued proliferation.

Further, client availability for these new approaches (LAA, MulteFire, LWA) is very limited at this time, and it remains to be seen how strongly they will be adopted by the mobile device ecosystem. On the other hand, Wi-Fi is integrated into virtually every smartphone – and also into laptops, tablets, and other consumer devices. With the use of 802.1X based authentication (which is also widely supported today), clients are able to associate and authenticate to a public Wi-Fi network using a cellular credential using EAP-SIM/AKA – indeed this is the basis for the Wireless@SG service.

Wi-Fi network discovery can be accomplished via a well known SSID, such as Wireless@SG. Additionally all of the major mobile device OSs now support Hotspot 2.0 technology, which automates the network discovery and selection function, allowing the client to connect to any SSID that supports authentication

of its credential. With either a well known SSID or Hotspot 2.0 approach, Wi-Fi offloading of cellular data traffic becomes transparent to the end user. The broad availability of both networks and clients supporting these mechanisms ensures that Wi-Fi offloading will continue to be the best way to move cellular data over unlicensed spectrum for the foreseeable future.

Conclusion

Thank you for the opportunity to provide Ruckus' input to IMDA on these matters. If you have any questions, or require additional information, please let me know.

Sincerely,

David A. Wright